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# Strategic Uncertainty and Risk Attitudes: The Experimental Connection*

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## Resumen

Este trabajo aporta evidencia experimental sobre la relación entre la aversión al riesgo y las creencias de los jugadores sobre las acciones que tomarán sus rivales en un juego del Dilema de Presos. Los resultados más relevantes son: (i) los aversos al riesgo tienden a pensar que su rival no cooperará, (ii) los amantes del riesgo dan

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mayor probabilidad de cooperación a sus rivales y (iii) finalmente, los sujetos que consideran que su rival es racional son más aversos que aquéllos que piensan que su oponente cometerá algún error.

**Palabras clave:** teoría de la utilidad esperada, riesgo estratégico, dilema de presos.

## Abstract

In this paper we obtain empirical evidence of the relationship between individuals' risk attitudes and individuals' beliefs on their rival's choices in the Prisoners' Dilemma game. We find that (i) risk-averse subjects seem to think that their opponent will defect, (ii) risk-loving individuals tend to think that their opponent will cooperate with higher probabilities, and (iii) finally, those subjects who believe that the rival will behave rationally are more risk averse than those subjects that believe that the rival will make a mistake, who on average are risk neutral.

**Keywords:** Expected utility theory, Risk attitudes, Strategic risk, Prisoners' Dilemma.
**JEL Classification:** C91, C71, D81

## 1. Introduction

Economic theory rationalises human behaviour by assuming that it is the output of an optimisation problem, in which the decision maker maximises his utility. To this end, it is assumed that economic agents are endowed with a utility function which complies with several properties. In strategic environments, decision makers are assumed to form beliefs about their rivals' intended play and to act accordingly, i.e., by maximising expected utility. However, economic theory does not impose any conditions to the factors affecting the formation of beliefs. Even more, this seems an empirical rather than a theoretical question.

In this paper we perform an experimental investigation about the relationship (if any) between some properties of the utility function and the beliefs hold by decision makers in strategic environments. In particular, we are interested in the interaction between attitudes toward risk (pure risk) and beliefs in strategic environments (strategic risk). We will analyse this interaction in one of the most popular games: The Prisoners' Dilemma.

We will use the experimental results reported in Brañas-Garza and Morales (2004, BGM hereafter). These authors analyse subjects' behaviour in two games in order to

get knowledge of subjects' beliefs on rival's cooperativeness in the Prisoners' Dilemma game. In this paper we complement that analysis by incorporating a third «game» included in those experimental sessions but not reported in BGM. The third game was precisely aimed at getting knowledge of subjects' attitude toward risk.

Our findings indicate that attitudes toward risk are related to beliefs in strategic environment. We do observe that subjects with more risk aversion think that their rival will defect in the Prisoners' Dilemma game. In contrast, risk-loving subjects think that their opponent will cooperate with positive probability. Also, those subjects who believe that the rival will behave rationally are more risk-averse than those subjects that believe that the rival will make a mistake, who on average are risk neutral.

Up to now, there exists little evidence on the existence of any relationship between the strategic uncertainty and the attitudes toward risk. Sabater and Georgantzís (2002) study the role of risk aversion on players' behaviour in repeated prisoners' dilemma games. They find that risk aversion relates negatively with the disposition to cooperate. Specifically, the most risk-averse players choose Nash strategies more often than the less risk-averse ones. However, these authors focus on the importance of the risk aversion on the players' *actions*, not on the *beliefs* they hold, like us.

The rest of the paper is structured as follows. Section 1 explains the experimental design describing in detail the methodology and procedures. Section 2 presents the main results obtained from the experiment and section 3 concludes.

## 2. Design

Our research is based on the comparison of a subject's responses across two parallel situations, both involving uncertainty and risk. To rationalise behaviour, we will assume that the decision-makers behave as maximising expected utility.

Under this within-subject design, first we propose an experimental setting to test for our individuals' risk attitudes. Second, subjects face two different strategic games: An Entry game and a Prisoners' Dilemma game.

This second setting allows us to estimate the subjects' beliefs about their rival's behaviour. Each of the two experimental settings is described in the following subsections[2].

[2] Although this design may generate some order effects, BGM treatment 2 (not reported here) rejects any rank-order effects. BGM treatment 2 consist only of a PDG without any previous game

## 2.1. *Testing for attitudes toward risk*

In decision making under risk, there exists a wide variety of elicitation and classification techniques according to the attitudes toward risk (asking individuals the willingness to pay, the willingness to accept or using a lottery choice procedure). The experimental literature shows that subjects exhibit a significant degree of heterogeneity in the attitudes toward risk and that this is an important issue to take into account in games like auctions, negotiation or investment decisions. It is important to point out that *our objective here is to control the individual behaviour under risk* and to obtain a classification based on the risk attitudes distribution, not to measure attitudes toward risk.

To test for individual risk attitudes, we consider a slightly modified version of Holt and Laury (2002). Concretely, we ask subjects to choose between a sure amount of money and a lottery. However, in contrast to the general tendency in the literature, we do not offer directly the lottery but the following two-player game[3]:

Figure 1. Game 0

| | E | NE |
|---|---|---|
| E | 4,4 | 8,3 |
| NE | 3,8 | 0,0 |

In this game, individuals were told that they were the player 1 and that player 2's choice would be selected by the toss of a fair coin; hence, player 2 would play each action with a 50% of probability. The sequence players followed was: First, they had to decide which strategy they will play and, second, they had to fill in the following payments card (see figure 2).

(for 55 subjects) and not any difference is found between the data used in this paper and treatment 2 data set. Both the Mann-Whitney ($Z = -0,78$; $p = 0,43$) and Kolmogorov-Smirnov ($Z = 0,30$; $p = 1,00$) tests do no reject the null hypothesis of equal distribution between data from treatment 1 (used here) and treatment 2 (rank-order control).

[3] The characteristics of this game are similar to those of the games used in the second experimental setting.

Figure 2. Payment Card

| | | | |
|---|---|---|---|
| 1ST CHOICE: | PLAY | OR | 1 EURO FOR SURE |
| 2ND CHOICE: | PLAY | OR | 2 EURO FOR SURE |
| 3RD CHOICE: | PLAY | OR | 3 EURO FOR SURE |
| 4TH CHOICE: | PLAY | OR | 4 EURO FOR SURE |
| 5TH CHOICE: | PLAY | OR | 5 EURO FOR SURE |
| 6TH CHOICE: | PLAY | OR | 6 EURO FOR SURE |
| 7TH CHOICE: | PLAY | OR | 7 EURO FOR SURE |
| 8TH CHOICE: | PLAY | OR | 8 EURO FOR SURE |
| 9TH CHOICE: | PLAY | OR | 9 EURO FOR SURE |
| 10TH CHOICE: | PLAY | OR | 10 EURO FOR SURE |

As we can see, the payments card is a set of ten decisions where each of them consists of choosing between a sure amount of money (ranked from 1 to 10) or playing the game. We assume that when filling the payment card, the individual considers that the relevant row of the above game is the one corresponding to his chosen strategy. Hence, the game reduces to a lottery and therefore, an individual would choose to play the lottery if the sure monetary payoff is lower than the certain equivalent of the lottery. Note that the amount of money at which the individual switches from playing the game to the sure amount of money is precisely the certain equivalent of the lottery, which we will named the elicited value of the game.

As an example, consider the dominant strategy for the player 1. It gives either 4 or 8 with the same probability. This implies that under Expected Utility Theory, we can only characterise the respondents' attitudes toward risk into this interval. So, a value of 6 would mean that he is a risk neutral person. If the value is lower than 6, the individual would be risk averse and risk loving if his value was greater than 6.

There exist however two experimental behavioural patterns under risk that the expected utility framework does not explain, that is, the attraction to and the repulsion from chance —see Pope (1997) for a discussion of the «utility and disutility of chance» from both a descriptive and normative point of view and Albers et al. (2000) for experimental evidence for attractions to chance. In our experiment, an elicited value smaller than the minimum available payoff might reflect repulsion from chance. In contrast, an elicited value greater than the maximum available payoff might reflect an attraction to chance.

In this research, rather than excluding these individuals we will incorporate them in our analysis into two categories: Repulsion and Attraction from chance. Hence, we

might have up to five categories of risk attitudes to classify individuals according to the elicited value in game 0: Repulsion (1-3), Aversion (4-5), Neutrality (6), Loving (7-8) and Attraction (0-10).

## 2.2. *Eliciting values on rival's cooperativeness on the Prisoners' Dilemma*

This section summarises the methodology followed by BGM. The experiment involves two games: An Entry game and a Prisoner's Dilemma game. Individuals were first asked to choose the strategy (Enter or Not enter) in each game and, after playing each game, they were invited to fill in the payments card. Figure 3 plots the payoffs matrices of both games.

Figure 3. Game 1 & Game 2

| | E | NE |
|---|---|---|
| E | 4,4 | 8,3 |
| NE | 3,8 | 0,0 |

Entry Game

| | E | NE |
|---|---|---|
| E | 4,4 | 8,3 |
| NE | 3,8 | 7,7 |

Prisoner's Dilemma

Two remarks are in place.

First, note that game 1 is the same as game 0 used to characterize the players' risk attitudes. However in game 1, the player 2 is a subject randomly selected among all participants and therefore player 1's subjective beliefs on player 2's actions play an important role in player 1's behaviour. In particular, his belief or his subjective probability of player 2 choosing the dominated strategy critically affects his value of the game elicited by the payments card.

Second, notice that the unique difference between games 1 and 2 is the outcome yielded by the pair of the dominated strategies (NE, NE). In particular, both games are dominance solvable and the unique prediction based on dominance criteria is that players will choose the dominant strategy E. But in the Entry game there is no scope for cooperation whereas in the Prisoners' Dilemma game comes out the possibility of cooperation.

Our methodology is to compare players' elicited values across these two games. Note that any difference in values, i.e. any change in beliefs, can be interpreted as motivated by the appearance of the cooperative dilemma. Hence, the comparison of

players' values across games provides us with information about beliefs and also about how players regard the possibility of cooperation in the Prisoners' Dilemma. As a result of the comparison between the elicited values across the two games, subjects can be classified according to the following taxonomy[4]:

- *Rational rival*: This individual thinks that his rival will play the rational strategy in both games with probability 1. This implies that the elicited value in both games corresponds to the minimum available payoff[5].
- *Trembling-hand rival*: This individual believes that the rival will use the same completely mixed strategy in both games. That is, he thinks that with the same positive probability, the rival will deviate from the rational strategy in both games.
- *Payoffs rival*: This individual thinks that his rival will use a different mixed strategy in each game. That is, he supposes that the social issue attached to the Prisoners' Dilemma game will affect his rival's behaviour.

We will now review our experimental findings in the next section.

## 3. Results

We first present a table displaying the number of experimental subjects in each category. Note that individuals are classified by both beliefs and risk attitudes. Quite fortunately, there are subjects in every category with the unique exception of Rational rival-Attraction players (see table 1)[6].

[4] In BGM there was also a classification according to played actions. In this paper, however, we do not draw such distinction because our emphasis is on beliefs rather than actions.

[5] Brosig (2002) performs a different classification of individual predictions about rival actions in PD games. These predictions are based on pre-play communication without monitoring.

[6] Using Wilcoxon non-parametric test for 2-related samples we observe that there exist strong differences ($x^2 = -2,79$; $p = 0,00$) between valuation in game 0 (risk aversion test) and game 1 (entry game). This result illustrates that individuals perceive the difference between playing against a machine and against a human rival.

Table 1. Experimental Results

| | RATIONAL | T-HAND | PAYOFF | TOTAL |
|---|---|---|---|---|
| REPULSION | 3 | 1 | 2 | 6 |
| AVERSION | 10 | 7 | 16 | 33 |
| NEUTRAL | 4 | 9 | 12 | 25 |
| LOVING | 2 | 9 | 6 | 17 |
| ATTRACTION | 0 | 2 | 1 | 3 |
| TOTAL | 19 | 28 | 37 | 84 |

There are two obvious ways to analyse the relationship between attitudes toward risk and beliefs. The first one would be the study of the distribution of beliefs (strategic risk) conditional to risk attitudes. The second one would be to explore the distribution of risk aversion within each group of individuals ranked by their beliefs.

In the next sections we undertake both.

## 3.1. *Strategic Risk conditional to Risk Attitudes*

In this section we first cluster subjects conditional to their attitude toward risk. This analysis will help us to understand whether risk attitude affects the formation of beliefs on rival's actions in the Prisoners' Dilemma game.

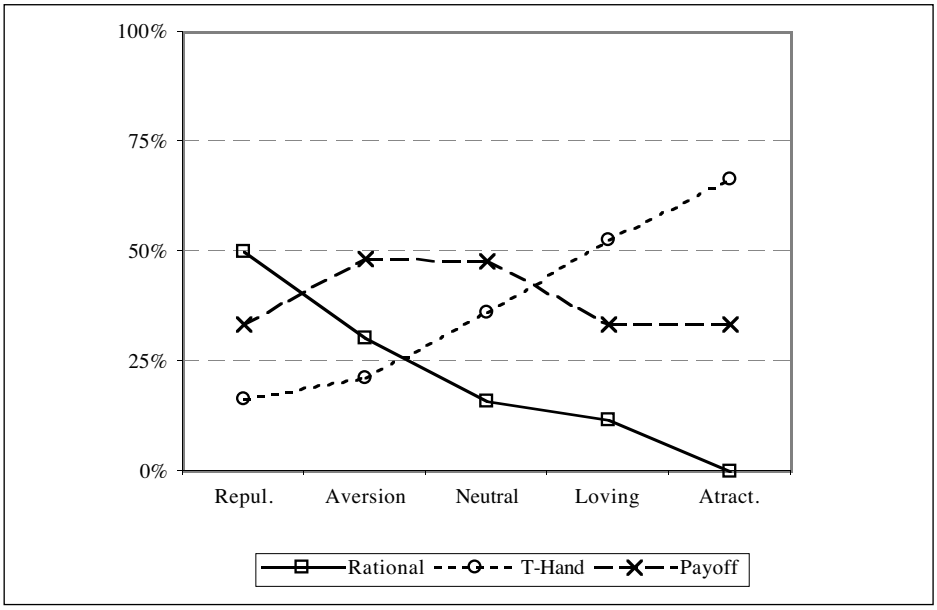
Table 2 and Figure 4 illustrate the experimental results.

Table 2. Beliefs By Risk Att. (%)

| | RATIONAL | T-HAND | PAYOFF | TOTAL |
|---|---|---|---|---|
| REPULSION | 50,0% | 16,7% | 35,3% | 6 |
| AVERSION | 30,3% | 21,2% | 48,5% | 33 |
| NEUTRAL | 16,0% | 36,0% | 48,0% | 25 |
| LOVING | 11,8% | 52,9% | 33,3% | 17 |
| ATTRACTION | 0,0% | 66,7% | 33,3% | 3 |
| TOTAL | 19 | 28 | 37 | 84 |

Figure 4 give us a clearer picture. Rational rival individuals are more probable in categories of enhanced risk aversion while T-Hand rival subjects are more numerous in risky stadiums. The former shows a decreasing trend along the risk axis and the later run in opposite direction. However, Payoff Rival subjects do not follow any clear trend, being equally distributed along the risk intervals.

Figure 4




By focusing on rational rival players, we can get knowledge of the evolution of the fraction of the population who believes that their rival will behave rationally in the Prisoners' Dilemma. Our result shows that the higher the risk aversion, the higher the belief that the rival will be rational. Hence, there is positive correlation between risk aversion and beliefs on rival's rationality[7].

The evolution of T-Hand players suggests that the higher the risk love, the higher the belief that the rival will make a mistake and play the cooperative action.

Finally, by considering the evolution of payoffs rival players we can get knowledge of the fraction of the population who believes that cooperation is an issue for their rival in the Prisoners' Dilemma. Our results suggest that there is no correlation between this belief and the attitude toward risk.

Our interpretation of the above results is as follows. Notice that in the Prisoners' Dilemma game and, regardless of the action played by a given individual, the higher his belief on the rival playing the cooperative action, the higher his payoff. Hence, it

[7] Recall that we use rational in the traditional sense (EUT).

is as if a risk averse player is pessimistic about getting a good payoff whereas a risk loving player is somehow optimistic about it.

## 3.2. *Risk Attitudes conditional to Strategic Risk*

In this section we perform a complementary analysis. We classify subjects by beliefs and then we characterize their attitudes toward risk, i.e. specifically we analyse their certain equivalent. This sort of analysis is appropriate to detect different attitudes toward risk among different group of individuals.

Next table illustrates the main descriptive statistics for each group: Rational rival, T-Hand rival and Payoff rival subjects.

Table 3. Descriptive statistics

| | RATIONAL | T-HAND | PAYOFF |
|---|---|---|---|
| N | 19 | 28 | 37 |
| AVERAGE | 4,68 | 6,21 | 5,40 |
| MEDIAN | 5 | 6 | 6 |
| MODE | 4-5 | 6 | 6 |
| ST. DEV. | 1,63 | 1,61 | 1,38 |
| VAR. | 2,67 | 2,61 | 1,91 |
| MIN. | 1 | 1 | 3 |
| MAX. | 7 | 10 | 9 |

A simple visual inspection reveals differences on the average certain equivalent among groups (see row 2, table 3). T-Hand rival subjects are, on average, risk-neutral but both Payoffs rival and Rational rival subjects are risk-averse.

The statistical analysis confirms differences among distributions. Kruskall- Wallis non-parametric test for $k = 3$ unrelated samples rejects the null hypothesis of equal distribution of samples ($X^2$ =11, 56; p = 0, 00), that is, observations are not drawn from the same population. Median test ($X^2 = 6, 03$; p= 0, 04) also rejects for a 5% significance level**.** So rational, t-hand and payoffs individuals differ in their attitudes toward risk.

In order to clarify results we run 2-samples tests.

- Rational rival subjects vs. T-Hand rival subjects: Mann-Witney test rejects ($Z$= –3, 22; p = 0, 00) equal distribution among samples; Kolmogorov-Smirnov rejects ($Z$ = 1, 34; p = 0, 05) for ?= 5%. Then, Rational rival and T-Hand rival individuals are different in risk aversion.

- Rational rival subjects vs. Payoff rival subjects: Mann-Witney test does not reject ($Z$= –1, 39; p = 0, 16) equal distribution and Kolmogorov-Smirnov also does not reject ($Z$ = 0, 701; p = 0, 71) the null hypothesis. So, we do not observe differences, in risk aversion, between Rational rival and Payoff rival individuals.
- Payoff rival subjects vs. T-Hand rival subjects: Mann-Witney test rejects for *?* =1% (Z= –2, 38; p=0, 01) equal distribution among samples but Kolmogorov-Smirnov also does not reject ($Z$=1, 15; p =0,, 15) the null hypothesis. Summarising, there exist weak differences among T-Hand rival and Payoff rival individuals.

Table 4 below illustrates the distribution of population (relative frequency in %) by certain equivalents in each group.

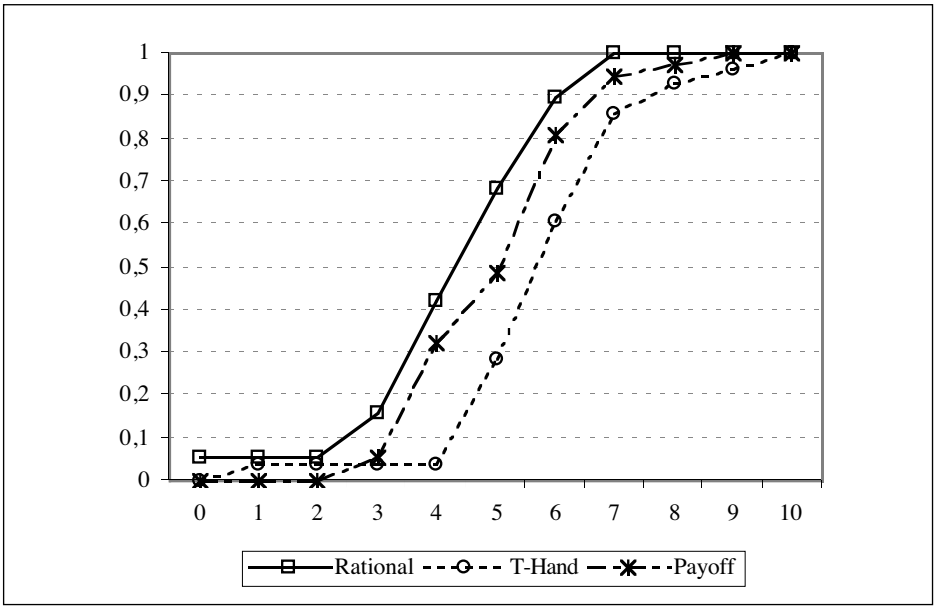
Table 4. Relative frequencies by groups (%)

| | REPULSION | | | AVERSE | | NEUTRAL | LOVING | | ATTRAC. | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| RATIONAL | 5 | - | 10 | 26 | 26 | 21 | 10 | - | - | - |
| PAYOFF | - | - | 5 | - | 27 | 16 | 32 | 13 | 2 | - |
| T-HAND | 3 | - | - | - | 25 | 32 | 25 | 7 | 3 | 3 |

Figure 5 illustrates the cumulative frequencies of the certain equivalent in each group. Observe that the largest percentage of averse individuals and the smallest percentage of risk loving subjects are found within the Rational group. Exactly the opposite to the T-Hand category which displays the largest risk loving share and the smallest percentage of risk averse subjects.

Clearly, both groups run in the opposite direction. In the Payoff group, the risk attitudes distribution is more balanced, subjects are distributed more uniformly along the risk categories.

Figure 5. Cumulative Frequencies




## 4. Concluding remarks

In this paper we have investigated empirically the relationship between attitudes toward risk and beliefs on rival cooperativeness in the Prisoners' Dilemma game.

We have found empirical evidence that risk attitudes affects the beliefs on the rival's choices: (i) The higher the risk aversion, the higher the belief that the rival will behave rationally, and (ii) The higher the risk love, the higher the belief that the rival will make a mistake and play the cooperative action.

We offer an interpretation of these findings. Notice that in the Prisoners' Dilemma game and regardless of the action played by a given individual, the higher his belief on the rival playing the cooperative action, the higher his payoff. Hence, it is as if a risk averse player is pessimistic about getting a good payoff whereas a risk loving player is somehow optimistic about it.

Also, in a complementary analysis, we have also found that those subjects who believe that the rival will behave rationally are more risk averse than those subjects that believe that the rival will make a mistake, who on average are risk neutral. Statistical analysis confirms these ideas.

Given that a very few research has been done in this field, this paper has intended to open a research agenda on the «connection» between beliefs and risk attitudes.

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